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IX.—*On the Development and Propagation of* Sphæroplea annulina. By Dr. Ferdinand Cohn*.

Up to last year there were few botanists who believed in the sexuality of the Algæ. Thuret's observations on the antheridia of the Fucaceæ did indeed open a new prospect, in demonstrating the impregnation of the reproductive spores by minute spontaneously-moving spermatozoids (*antherozoids*, Thuret); yet this discovery, so long as it remained isolated, appeared rather to remove the Fucaceæ from the class of Algæ, just as the previously discovered sexuality of the Characeæ has altered the position of those plants in many systems. The observations of Pringsheim†, laid before the Academy in March last, have proved that one of our freshwater unicellular Algæ also possesses separate sexual organs. Having discovered spermatozoa in the "*horns*" (previously suspected to be antheridia) of *Vaucheria*, and traced their entrance into the orifice of the sporangial cell, Pringsheim has established the fertilizing process in the most remarkable manner, and grounded upon this the conjecture that difference of sexes exists in *all the rest of the Algæ*, and that the resting-spores, the true reproductive organs of these plants, are in all cases impregnated by spermatozoa and are not capable of germination without this. The history of development which I am about to sketch in the following pages affords new evidence in favour of this proposition: as it rests upon a totally independent series of observations, almost simultaneously performed, and reveals most remarkable modifications of this process, it may still lay claim perhaps to an especial interest.

* Translated from the 'Monatsbericht' of the Berlin Academy, May 1855, by Arthur Henfrey, F.R.S. &c.

† Annals of Nat. Hist. 2nd Ser. xv. p. 346.

Sphæroplea annulina, Ag., is one of the rarer freshwater Algæ, which is not observed, like most of these plants, everywhere and at all seasons, but only at long intervals and under peculiar circumstances; it consists, like all the Confervæ, of cells of variable length, connected in a single row into long filaments, and is characterized by a peculiar arrangement of the chlorophyll. Ehrenberg has already remarked that it covers extensive surfaces about Berlin with a red coating, and hence may have given rise to traditions of "blood-rain." Near Bremen, where it was discovered by Treviranus, it occurs upon flooded tracts. At Breslau I found it the first time at the end of October, last year, in a potato-field which had been laid under water by the great overflow of the Oder in the last week of August. The *Sphæroplea* covered the field, which had dried again after the retreat of the water, as an almost uninterrupted felt, of a beautiful red-lead or vermilion colour on the smooth upper surface, and green on the under side, where it was disentangled into the separated filaments. The red colour depended upon the spores with which the filaments of the *Sphæroplea* were completely filled up; only those filaments which were exposed to light and air on the surface of the felt fructified; the under side, resting on the ground, contained only vegetative filaments of the normal green colour.

The structure of the *Sphæroplea*-spores is very simple; they are red globules, usually from 1–125 to 1–100''' in diameter, surrounded by two hyaline membranes, of which the inner lies close upon the contents, while the outer is somewhat separated and is elegantly creased. The spores of *Sphæroplea* are usually described as stellate; Kützing however states that they are encircled by spiral bands. Both these assertions are justified to a certain extent: it depends upon the position of the spores whether they look like many-rayed stars, or as longitudinally streaked, smooth-bordered globes. The outer coat of the spore is so folded that the folds meet at the two poles of the globe like so many meridians. Hence if we look at the pole of a spore, the folds are seen surrounding the globe like a frill, in a sharp-angled zigzag; while if we look upon the equator of the spore with the axis parallel to the object-glass, the folds may be traced in their whole course as longitudinal lines. In many spores, especially the large ones, the plaiting of the outer coat is very irregular, and forms merely wart-like elevations without any definite arrangement. Sulphuric acid causes an expansion of this coat, but does not destroy it; iodine and sulphuric acid colour it bright yellow.

The contents of the spores consist of rather large starch-granules, and protoplasm which is coloured bright vermilion-red by a peculiar colouring matter; they contain a red oil which stands in the closest relation to chlorophyll, and is equally produced from this and transformed into it. In normal conditions this oil is diffused so minutely in the colourless plasma, forming a kind of emulsion, that it appears in infinitely small, red globules which might be confounded with the so-called protoplasm-granules; their oily nature may be ascertained, however, when the spores die or are destroyed by chemical reagents, as the red globules then become confluent into large red-lead-coloured drops, strongly refracting light, soluble in æther, are coloured bluish-green by iodine, and by a somewhat longer action of sulphuric acid acquire a blue colour; this last reaction exactly resembles that of sulphuric acid on chlorophyll; hence it is not improbable that the acid converts the oil into the related substance chlorophyll. If the sulphuric acid remains long in contact with the spores, the latter become bleached; the action of light produces the same effect upon the spores when dead. The red colouring matter of the spores of *Sphæroplea* is different from the erythrophyll of leaves and flowers, but it occurs in the spores of *Bulbochæte*, as shown by Pringsheim, in *Protococcus nivalis* and *pluvialis*, *Chroolepus Iolithus*, and many other Algæ, also in *Euglena sanguinea*; in every case it is changed, in the course of development, into green chlorophyll, and *vice versâ*. The spores of *Sphæroplea* present a remarkable resemblance to the red, stellate reproductive bodies which Ehrenberg pointed out in the genus *Volvox* (*V. stellatus*), and which, according to my investigations, contain both red oil and starch-granules.

The course of development of *Sphæroplea* being hitherto altogether unknown, and in fact the germination of the resting-spores of the Algæ generally never having been observed, except in the Conjugatæ and *Vaucheria*, I resolved to turn to account an immense mass of *Sphæroplea*-spores at my disposal, in an investigation, and accordingly, at the beginning of October 1854, I placed a portion of the red felted mass in a vessel of water. A putrefaction immediately took place, through which the cells of the filaments were dissolved; while the spores thus set free,—which, as a microscopic examination showed, protected by their two membranes, underwent no alteration whatever,—subsided to the bottom of the vessel in countless numbers as a reddish mud. Notwithstanding that the glass now stood all through the winter in the window of a warm room, I could not detect any change in the spores before March; the germination showed itself first after a few mild spring days, and it occurred *simultaneously* in two separate vessels. In order to ascertain whether a six-months' rest was actually necessary to the *Sphæroplea*-spores, I placed a fresh portion of the filamentous mass in water, at the end of March; in this case I observed germinating plants *five days* *after*. The germination took place still more quickly in subsequent third and fourth experiments, wherein it occurred in forty-eight hours, with spores which up to that time had been kept in the herbarium. I am quite unable to explain the enigmatical hastening of the germination in the spring months; it could scarcely have depended on the greater heat, for the room was heated to a higher temperature during the winter. At the same time the germination of the *Sphæroplea*-spores occurred relatively rarely in cultivation, so that it went on through many weeks, and the majority of the spores still remained unchanged; while in the natural locality, the potato-field above mentioned, by the middle of April, about which time the field was again flooded, the spores had all germinated, and no trace of the red felted mass remained, while the standing water was full of the green filaments of *Sphæroplea*.

The germination of the spores of *Sphæroplea* differs from everything formerly known of the development of the Algæ and of plants generally; on the other hand, it agrees surprisingly with simultaneous observations on the germination of *Bulbochæte** already published by Pringsheim in these Reports. The youngest germs of *Sphæroplea* that I perceived were spindle-shaped corpuscles from $\frac{1}{190}$ to $\frac{1}{130}$ of a line in diameter, and about $\frac{1}{40}$ of a line long, running out at both ends into long filiform points which were irregularly curved and twisted, and increased the total length to $\frac{1}{14}$ of a line and more. These germinating plants resembled in shape, even indistinguishably, that interesting species of *Closterium* which Ehrenberg has described and figured as *C. rostratum*. The contents of the germ displayed every intermediate stage from the red of the spore to the green of the developed plant; the red and green were mingled in a most elegant manner, either with the red oil-globules accumulated at one end and the green chlorophyll at the other, with a colourless band separating them in the middle; or bands of red and green alternated; or the whole contents were green sprinkled with red globules. At first sight of these germs, I perceived that their dimensions were much smaller than those of the spores from which they must have been produced; hence they evidently must have originated from a part, not the whole, of the spore. Added to this, I never found a germinating plant sticking in the membranes of the spore, but always scattered free in all parts of the water; so that I was necessarily driven to the conjecture that these portions must have been discharged from the spores as "swarming-cells." I was soon enabled to confirm my conjectures by direct observation.

* Ann. Nat. Hist. Ser. 2. xv. p. 349.

When the spores of *Sphæroplea* are about to germinate, in the first place their contents are metamorphosed, acquiring a peculiar granular organization and assuming a colour more brown-red, a lighter circle becoming visible in the middle. The red of the spore is frequently changed into green before germination, the conversion advancing gradually from the borders to the centre. The *contents of the spore next divide*, first into two, then into four or eight portions; these portions break through their double membrane and emerge into the water as free 'swarming-cells.' In the small number of spores which germinated daily out of the enormous quantity present, I never succeeded in catching the moment of the exit, and therefore I do not know how the two coats of the spore are torn; but the empty membranes are often met with, a mere remnant, at most, of unconsumed contents remaining in them; I also found spores with undischarged 'swarm-cells' dancing about actively in their interior. The whole process differs from what Pringsheim observed only in so far, that in *Bulbochæte* a long cylindrical germinal filament escapes from the spore, and the contents of that are formed into free 'swarming-cells,' while in *Sphæroplea* this operation is completed within the spore itself; but I often met with spores from which the outer stellate membrane had been stripped, and the contents had begun to divide within the inner smooth coat.

The 'swarming-cells' (*zoospores*) which are formed in the interior of the spores of *Sphæroplea* have an exceedingly elegant shape, which however, like their size and colour, is subject to considerable variation. Ordinarily they are globular or short cylindrical corpuscles $\frac{1}{190}$ to $\frac{1}{150}$ of a line long, of a splendid carmine or vermilion colour, furnished at one end with a short colourless head from which extend two long cilia. Other swarming-cells are larger and pear- or spindle-shaped; these evidently derive their origin either from a larger fractional part or from larger spores: I met with globular swarming-spores even as much as $\frac{1}{140}$ of a line in diameter, not inferior in size to the ordinary spores; and perhaps these might have consisted of the total contents of such a spore swarmed out in one mass. Many swarming-cells are of two colours; the part next the beak red, the rest green; or a green border surrounds a red centre; but the colourless head or beak, with the cilia, is always evident. Their movements last for many hours, and exhibit that vigorous, and yet at the same time lazy character which distinguishes for example the swarming-spores of *Œdogonium*, and still more those of *Chlamidomonas pluvialis*, which are similar also in their colour and the number of their cilia. The long pauses which occur from time to time in the movements of these swarming-cells are remarkable; one might imagine sometimes that they had settled quite to rest, but after an interval of an hour or more they suddenly recommence their old revolutions.

At the time when the swarming-cell breaks through the membrane of the spore of *Sphæroplea,* it possesses no cellular membrane; but it produces this while still in motion, so that it becomes distinctly surrounded by a delicate, young, and very elastic cellulose coat. When the swarming-cell germinates, this membrane becomes rigid and prolonged at both ends so as to produce the spindle-shape; these ends grow out rapidly into capillary points, which constantly increase in length; the middle of the germinating cell then likewise extends itself, the ends being pushed still further apart, and the entire cell is thus rendered at once longer and thicker. The originally homogeneous, finely-granular contents of the swarming-cell is changed in germination, the remainder of the red oil becoming rapidly converted into chlorophyll, the germinating plant thus acquiring a uniform green colour; but even in the earliest condition colourless bubbles (*vacuoles*) are found in the green plasma, these vacuoles containing a fluid of less density, while the chlorophyll between them is compressed, and thus assumes the form of green rings standing at certain distances apart. In these streaks large starch-globules are soon secreted, and by the time the germinating plant is $\frac{1}{13}$ of a line long, it has already assumed the full character of the cells of *Sphæroplea.* It continues to increase in length and breadth, retaining however its Closterium-like shape. I met with colossal spindle-shaped cells half a line and more long, prolonged into capillary points at both ends. *Sphæroplea* is the only Conferva known to me that *never possesses a root*; in all other genera one end of the germinating filament, avoiding the light, grows downward into an organ of attachment, while the other differently formed end grows by apical development into the proper filament. In *Sphæroplea,* not only are both extremities of exactly the same shape from the first origin, but no apicular growth occurs, at least not after the capillary ends are completed; the cells here grow in the middle. Since the green rings in the cells of *Sphæroplea* fix the relative positions of their points, the places where the growth takes place may be readily observed, the number of rings being constantly multiplied, by the division of the old, previously formed ones. But a minute investigation of this subject would carry us too far from the object of this notice. After some time the germ-cell divides in the middle, and with the enlargement of the plant the number of cells is increased: the length of the cells is strikingly unequal, for while in some cells they cannot be perceived, other cells are only $\frac{1}{4}$ or $\frac{1}{8}$ of a line. But in the longest, many-celled filaments, the fine capillary parts of the elongating ends may always be observed,—a fact hitherto overlooked.

The contents of the full-grown cells of *Sphæroplea* exhibit most elegant structures, the comprehension of which is essentially furthered by the interesting investigations of Al. Braun. The constituents, colourless protoplasm, green chlorophyll, aqueous fluid and starch-granules, are distributed in a peculiar manner, the aqueous fluid forming large bubbles or vacuoles which attain a diameter almost equal to that of the cell, and hence stand in rows, like pearls, often in contact at their poles, and flattened there so as to form seeming septa. In the interval between the vacuoles is compressed the green plasma with the starch-granules; and here further the space becomes disputed by numerous smaller vacuoles which are excreted from the plasma: under a low magnifying power the whole appears as if there was a regular alternation of narrow green and broad colourless rings. If the vacuoles are smaller and the chlorophyll is more abundant, the cell appears uniformly green,—more intense merely in the interval between the vacuoles. The vacuoles have an envelope of condensed plasma, so that when the whole is softened in water the vacuoles do not dissolve, but sustain themselves for a long time, like cells; but they are not permanent structures; their number and size are subject to constant alteration.

In the second half of April I first observed the *germinated filaments of* Sphæroplea *beginning to reproduce spores.* The regular arrangement of the green rings disappeared in particular cells; the vacuoles increased in number, so that the whole contents assumed the appearance of a green froth; the starch-globules were irregularly diffused through this. These were soon seen to become grouped together in twos or threes, and largish masses of the green plasma became accumulated around them; after a certain time the middle line of the cell was occupied by a great number of green lumps, at regular distances, the frothy matter being distributed between them. As the majority of the vacuoles gradually disappeared these lumps assumed the form of green stars, such as occur in pairs in the cells of *Zygnema,* remaining connected together by the green radiating filaments of plasma. Between each pair of these stellate masses a large vacuole was formed, which became flattened to level septa, so that the whole cell appeared as if divided into chambers by a number of parallel plates of plasma. In each of these chambers there began an uninterrupted metamorphosis of the green mass; the mucilaginous filaments were gradually retracted; the green substance contracted itself sometimes towards the right, sometimes to the left; in a short time the colourless plasma had become so distributed around the chlorophyll that the septa of the chambers separated, and the whole contents were broken up into a large number of *free globular masses,* which were sharply defined, composed chiefly of colourless mucilage, and enclosed in their centre an irregularly diffused, mostly laterally situated heap of chlorophyll. These masses, the *young spores,* then pass uninterruptedly through the most wonderful changes; at first they are in contact, and thus form by their adjacent boundaries the plasmic septa, which are consequently double; their substance becoming somewhat contracted, the two layers of these septa separate, the spores thereby becoming isolated; the chlorophyll in their interior is constantly changing its mode of distribution; the colourless mucilaginous envelope at one time contracts strongly, so that free, regular globules are produced; at another it expands again, so that they are flattened against their neighbours; or sometimes one becomes elongated laterally, and if a drawing is begun to be made, its shape has entirely altered before the sketch is completed. Finally, the nascent spores become rounded-off into smooth spheres, which however are still far larger than in the mature condition, and are not completely filled with chlorophyll. But the latter becomes diffused gradually more regularly in the spore-globe, while the colourless plasma is progressively more elaborated and excreted; consequently the spore is constantly becoming more condensed and diminished in size, and finally becomes a regular sphere composed entirely of a granular green substance, enclosing a few starch-granules, bounded externally by a smooth, clearly-defined layer of plasma; there is no cellulose membrane, the green structure is very soft, elastic, and under pressure passes away into mucus; it is to be regarded as a 'primordial cell.'

Long before the *contents* of the cells of *Sphæroplea* have become converted into young spores, peculiar changes have commenced in the *membrane* of their cells; it begins to change into *amyloid,* and therefore is now coloured purple-red or violet by iodine alone, without sulphuric acid. Evidently this is the commencement of the chemical metamorphosis of this membrane, which terminates in its total solution and sets free the ripe spores. *At particular points of the membrane small holes are formed* $\frac{1}{500}$ to $\frac{1}{300}$ of a line in diameter; I have counted from two to six of these orifices in each cell; the holes are more easily observed, as colourless spots, when the cell is coloured blue by sulphuric acid and iodine.

This course of development, by which they are transformed into *sporangia* with numerous *spores,* does not occur in all the cells of a filament of *Sphæroplea*; during the same epoch totally different processes are completed in a large portion of the cells. Here the green rings between the colourless vacuoles have gradually assumed a peculiar colour: they have become *reddish-yellow,* and the starch-granules have vanished. The orange-coloured substance is soon seen to acquire a peculiar organization; in it may be detected, at first obscurely, but progressively more distinctly, a separation into granules, then into little streaks, and *finally it becomes converted into myriads of short, confusedly crowded, little stick-shaped bodies.* The colourless vacuoles between the yellow rings take no part in this transformation. After this the rings begin to dissolve; suddenly one of the little stick-shaped bodies imbedded in the substance acquires its liberty and begins to move about in the cavity of the cell; more follow the example; the movement of these bodies becomes more and more rapid; in a few minutes the entire ring becomes decomposed into a countless number of actively moving corpuscles; then the stick-shaped bodies of a second and third ring enter into movement; finally the entire cell becomes filled with these corpuscles, which shoot about and circulate in all directions among each other. It is a wonderful sight to see their incredibly lively motions inside the parent-cell. The vacuoles partly persist during these processes, and they are seen swimming in the cavity of the cell as globular bubbles enclosed by a mucilaginous coat, often put into rapid rotation by the movements of the stick-shaped bodies.

One or more orifices are formed very early in these cells also, similar in shape and size to those which we have described in the sporangial cells. The first of the stick-shaped corpuscles is now seen to emerge through a hole into the water; it is soon followed by another, and at length by a whole herd at once. Their movements in the water are at first very weak; they adhere firmly together and oscillate about in masses; but in a short time they acquire greater energy and become scattered like dust, with infinite rapidity, through all parts of the drop of water. The corpuscles remaining in the mother-cell acquire a more rapid motion the freer the space left them; but their number gradually diminishes, and within a few hours all the moving corpuscles have left their parent-cell. This is then quite empty, and the orifices of exit can be perceived very distinctly; empty cells of this kind have been observed before, but their peculiarities could not be explained. The orifices often become stopped up by a vacuole, which with its mucilaginous membrane lies against the hole; this prevents the corpuscles from escaping, and I have seen them dancing about in their mother-cell after a lapse of twelve hours, then coming to repose and changed into yellowish vesicles. It is not rare to find in the cells of *Sphæroplea,* after the exit of the stick-shaped corpuscles, other larger, brownish globules, which often display a sluggish movement;

these structures, to which Al. Braun had already directed attention, under the name of *pseudo-gonidia*, are remnants of the cell-contents, unconverted into stick-shaped corpuscles, but which have nevertheless acquired a power of independent motion: perhaps they owe their origin to the fusion of a number of the corpuscles. I likewise sometimes found similar moving globes in the sporangial cells, mingled with the spores, and they appeared to have been formed simultaneously with the latter, out of the cell-contents. These are distinct from other abnormal, cell-like structures in the *Sphæroplea*-cells, some of which have a power of motion, as also from the parasitic Infusoria (e. g. *Trachelius trichophorus*) which make their way into the interior of the cells through the orifices; the former are very remarkable and varied; but I reserve a special examination of them for another occasion.

The corpuscles which 'swarm' out from the last-described cells of the *Sphæroplea*-filaments are elongated, bacilliform, and mostly $\frac{1}{250}$ of a line or more in length; their form reminds one of certain slender Curculionidæ. The posterior extremity is somewhat expanded, often spread out flat and of a yellow colour; one or more granules may often be distinguished in its interior; the anterior extremity runs out into a long narrow colourless beak, bearing at its end two long cilia, which are rendered clearly visible when the corpuscles are killed with iodine. These corpuscles differ strikingly therefore from the spermatozoids of *Vaucheria* discovered by Pringsheim, and which I have quite recently likewise had the good fortune to observe; as also from the spermatozoids of the Fucoideæ described by Thuret—whatever resemblance may exist in other respects—by the position of the two cilia; and they resemble herein many 'swarming-spores' of Algæ, especially those denominated microgonidia, with which they are intimately connected in morphological respects.

The movement of the bacilliform corpuscles in *Sphæroplea* is characteristic: when the energy is weak they oscillate, as if feeling about with the beaks; when the motion is more active they rotate on their *transverse* axis, like a stick fastened in the centre and rotated around this; their movement is distingushed by this from that of true 'swarming-spores,' which rotate on their longitudinal axis. Sometimes the corpuscles rotate upon themselves without moving from one spot, like a cat round its tail; but they mostly dart off in cycloids, frequently advancing with jerks and springs; more rarely they screw themselves straight onwards. A tendency to seek the light is indicated by their readily collecting at the side of the drop of water next to the window.

Not only did the external resemblance of these corpuscles to the spermatozoids of the Fucaceæ and *Vaucheriæ* give ground for concluding an analogous function,—I further succeeded in demonstrating *their fecundating power, by direct observation,* with an evidence such as can only be possessed by a fact of natural science: there can be no doubt that the active bacilliform corpuscles are the spermatozoids of *Sphæroplea,* and therefore the cells in which they are formed must be denominated the antheridial cells.

When the discharged spermatozoids have become diffused through the water, they are soon seen to assemble around those cells of a *Sphæroplea*-filament, the contents of which have become metamorphosed into spores. They dance about in the vicinity of these cells, attach themselves to the membrane, sometimes tearing away again, soon to return. After a while a spermatozoid approaches one of those little orifices, which we have already noticed as perforating the wall of the sporangial cells; here it fixes itself and pushes the slender beak into the hole. The posterior extremity is often too broad to pass in uninjured; then it screws itself forward with evident effort, the beak constantly working its way, compressing the elastic body; finally it succeeds in forcing its way through and entering into the cavity of the sporangial cell. In the mean time other spermatozoids have slipped in through various orifices; frequently three or four crowd at once into one orifice; the more slender corpuscles make their way, at the first attempt, in a remarkable manner swimming in wide curves, from the water, through the hole, without obstruction, into the cavity of the cell; after a time as many as twenty spermatozoids circulating about in its interior and 'swarming' round the young spores. These, as above described, are smooth spheres, more or less completely filled with chlorophyll, surrounded by colourless plasma, without cellulose membrane. The spermatozoids rush from one spore to another, as if electrically attracted and repulsed, so rapidly, that the eye can scarcely follow them; they often swarm from one end of the sporangial cell to the other; now and then the spores are thrown into slow rotation by the vibratile cilia of the spermatozoids, but this is only accidental and inessential, possibly only when the spores are in a very free position. I have seen the spermatozoids moving about in the sporangial cell for more than two hours; gradually their motion becomes more sluggish, they become adherent to the young spores, in such a manner that one or two spermatozoids become fixed to each spore, cleaving firmly to it with the beak and cilia, so that their body stands perpendicularly upon the spore. In this position they oscillate backwards and forwards for some time longer; finally they come quite to rest and apply themselves with their whole length against the surface of the spores; their body is converted into a drop of mucilage and loses its form; it appears as if a portion of the substance was absorbed endosmotically by the spore: a formal penetration of the spermatozoid into the spore certainly did not take place, for a remnant of it, perhaps the reddish drops, can long be seen attached upon the outside of the spore. However, *Sphæroplea* is not very well adapted for the investigation of the real act of impregnation, on account of the want of transparency in the green spores, notwithstanding that it offered an exceedingly favourable object for the earlier processes.

After a short time the impregnated spore becomes enveloped by a true cell-membrane, which at first can only be detected by the contraction of the contents by reagents, but subsequently can be readily seen by direct inspection, as it gradually separates further from the cell-contents. A second membrane is soon produced *beneath* the first, the second being originally in close contact with the contents of the spore, but subsequently folded in the stellate manner above described; the uppermost, earlier-formed coat is next thrown off, and such coats are found in the sporangial cells as empty vesicles among the spores—a 'moulting' or *ecdysis* already observed by Al. Braun. Finally there is produced under the stellate coat a smooth membrane, so that the impregnated spore of *Sphæroplea* bears an analogy with those of *Spirogyra* and *Zygnema*, and possesses likewise the three coats, the outermost of which however is thrown off, not in germination, but even before the spore is ripe. The contents of the spore are originally of a uniform green colour, in which several starch-granules make their appearance; subsequently they become opake, and pass through olive-green and reddish-brown, finally into a pure red. The number of the spores depends upon the quantity of chlorophyll which was present in the sporangial cell; their size is also very variable according as more or less of the green plasma is applied to the formation of one spore; although they are usually from $\frac{1}{125}$ to $\frac{1}{100}$ of a line in diameter, spores also occur which have double and even 100 times that magnitude; I observed elliptical spores which attained $\frac{1}{40}$, $\frac{1}{30}$, even $\frac{1}{23}$ of a line in the long diameter; I once met with a monster spore $\frac{1}{12}$ of a line in the long diameter, the red contents being enclosed in the papillose spore-coat just as usual. The approximate or distant arrangement of the spores, in one or several rows, is also liable to variation.

Sphæroplea annulina, although it always occurs as a multicellular filament, must be regarded as essentially a *unicellular* plant, in Nägeli's sense, since all the cells, without exception, even the terminal capillary-pointed cells included, take part in the propagation, and therefore the whole filament can only be viewed as a family of cells (cell-stock). The history of development here narrated reveals to us the fact, that, contrary to what has been hitherto imagined in unicellular plants, the individual is not immediately represented by each cell, but that these apparently equivalent cells become sexually differenced in exactly the same way as is the case in any of the most complicated animal or vegetable organisms; that consequently each individual cell is by itself barren, and can only be rendered capable of propagation by the cooperation of a cell of the other sex. We must therefore distinguish in the cells of the *Sphæroplea*-filament, *male and female cells*, or, for comparison with analogous organs in another kingdom of nature, sperm-vesicles and ovaries, which however must be more correctly conceived as independent, sexualized, elementary organisms. The process of impregnation in the Algæ has been found precisely similar in the three cases as yet known; in the *Fucaceæ, Vaucheriæ*, and *Sphæroplea*, the spermatozoids come into immediate contact with primordial cells destitute of (cellulose) membranes. The case of *Sphæroplea* is especially interesting, because there can be no question here of an accidental contact of the seminal elements; for if in *Fucus* the spores to be fertilized emerge upon the surface of the thallus—in *Vaucheria* the surfaces of the antheridia and sporangia come almost into immediate contact—in *Sphæroplea* the spermatozoids must often make their way through the water to an often far-distant mature female cell, and force an entrance through a narrow orifice. Easy as it is to observe the fact of the entrance of the spermatozoid, the force which guides these corpuscles through the wide surface of water and the crowd of countless animalcules and plants, to the female cells, and often makes them find their way through the narrow holes at the first attempt, remains still an enigma. I may also recall the fact that *Sphæroplea* is as far removed from alliance with *Vaucheria* as the latter from *Fucus*, and that since sexuality has been discovered in such diverse forms of the Algæ, there can scarcely be a doubt that it must only remain to be discovered in the rest of the Algæ, and indeed in all plants; I therefore cannot hesitate to give my adhesion to this conclusion of Pringsheim.

Whether the remarkable fact, that the spores of *Sphæroplea* do not always give origin, like all other spores and seeds, to one individual, but mostly to several swarming-cells, and therefore to several germ-plants;—whether this is connected with the action of one or more spermatozoids upon the nascent spore, I must leave unanswered; the only analogy to this fact is afforded by the origin of several embryos in the ova of the Planariæ. It is remarkable, that, according to Pringsheim's discovery, the fertilized spores of *Vaucheria* grow out into a germinal tube by direct elongation of the internal coat, like the spores of the Zygnemaceæ formed through conjugation, while the spores of *Bulbochæte*, and perhaps the spores of the Desmidieæ, likewise originating through conjugation, behave in the same way as those of *Sphæroplea*. This induces us to regard the latter fact as a peculiar form of the 'alternation of generations,' if we denominate the 'swarming-cells' produced from the spores of *Bulbochæte* and *Sphæroplea* an asexual generation, which by metamorphosis is converted at once into the *Closterium*-like germ, then by asexual division produces the sexual cells, till the cycle is concluded by the formation of the impregnated spores.

X.—*New Terrestrial Shells from Ceylon, with a General List of the Species inhabiting that Island.* By W. H. Benson, Esq.

Cyclophorus Parma, nobis, n. s.

Testa latissime umbilicata, planato-depressa, discoidea, tenuiuscula, confertim et arcuatim sericato-striata, saturate castanea, flammulis nonnullis pallidis spiram versus ornata, subtus interdum pallidiori; spira planata, apice nullo modo prominente, sutura profunda; anfractibus 5 convexis, ultimo antice descendente; apertura valde obliqua, ampla, ovato-rotundata, superne angulata, intus livide cærulea; peristomate duplici, interiori continuo, albido, ad dextram expansiusculo, exteriori breviter interrupto, expansiusculo, fusco-corneo; margine columellari subtus recedente, dextro prorsum arcuato; umbilico latissimo, minime profundo. Operculo tenui, corneo, $5\frac{1}{2}$-spirato, suturis intus extusque pulchre carinatis.

Diam. major 26, minor 23, alt. 6 mill.

Hab. in regione montana Insulæ Ceylon. Mus. E. L. Layard.

There are two specimens in the cabinet of Mr. Edgar Layard. The shell is easily distinguished from the other planorbular *Cyclophori* of Ceylon by its dark colour and depressed form, which recall those of *Pterocyclos hispidus*, Pearson, by its very wide and shallow umbilicus, and by the size and peculiar position of the aperture. The whorls of the operculum, which is of a clear horn-colour, are less closely wound than in *C. Cratera*.

Cyclophorus Cratera, nobis, n. s.

Testa late umbilicata, planulato-depressa, subdiscoidea, tenuiuscula, radiatim et confertim ruguloso-striata, vix nitidula, fulvo-cornea, raro castaneo-strigata; spira planulata, apice vix prominente, sutura profundiuscula; anfractibus 5 convexiusculis, ultimo longe lenteque descendente; apertura obliqua medioeri, subrotundata, superne angulata, intus albida; peristomate duplici, interiori continuo, acuto, breviter porrecto, exteriori expansiusculo, breviter adnato, albido; umbilico aperto, profundiusculo. Operculo tenui,